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NANOPARTICLES FOR DIAGNOSTIC IMAGING AND RADIOTHERAPY SPECIAL FEATURE: EDITORIAL

Editorial—nanoparticles for diagnostic imaging and radiotherapy

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In this special issue of *BJR*, we focus on the application of nanoparticles (NPs) for diagnostic imaging and radiotherapy. Nanotechnology in medicine is a rapidly expanding area with a range of clinical impacts. Driving research in this area has been the rapid development of novel nanoagents for targeted delivery of drugs in many disease types including cancer. For cancer, and specifically radiation-based therapies, the focus has been less on drug delivery but more on the potential of metal-based NPs to act as theranostics. Theranostic agents are designed to combine diagnostic information with therapy delivery, with metals, such as gold and gadolinium, being able to act both as image contrast agents for diagnostic imaging and radiosensitizers for therapy. An article by Hainfeld et al, in *BJR* in 2006,[1] was one of the first articles to highlight the promise of gold NPs, and a more recent review[2] highlighted the potential of gadolinium-based NPs as theranostics. It is now timely to highlight some of the key ongoing challenges in this area with a series of reviews from internationally respected NP researchers.

In an introductory commentary (doi: 10.1259/bjr.20150171), the key potential advantages of NPs combined with radiation are highlighted. This is the ability to expand the therapeutic window by targeting radiosensitization to the tumour and not normal tissues. This radiosensitization will be driven by both physical interactions of radiation with the NPs and biological parameters. To understand the physics of energy interactions with metal-based NPs, and make predictions regarding their potential dose-enhancement effects, radiation transport calculations including Monte Carlo modelling approaches have a key role to play, and these need to be applied for a range of monoenergetic and clinical beams. The biological response is heavily influenced by the design and pharmacokinetic properties of the NPs for use in combination with radiotherapy. It is important to consider aspects of administration, distribution, metabolism and expulsion which are influenced by alterations in NPs such as loss of colloidal stability, protein adsorption and chemical transformation.

To accurately quantify the spatial distribution of NPs, novel imaging technologies have to be utilized for *in vitro* studies. There are significant challenges in imaging at the NP scale and validating their uptake, distribution and localization in mammalian cells. Although electron microscopy is still the standard validation approach, it has practical limitations. One particular approach showing potential is the use of multiphoton plasmon resonance imaging (doi: 10.1259/bjr.20150170). Cell-tracking approaches have the potential to play an increasing important role in preclinical and clinical studies. There are significant gains to be made using labelling with NPs for *in vivo* applications for the application of cell-tracking approaches. Developing approaches here include the use of superparamagentic iron oxide and paramagnetic gadolinium and manganese NPs for MRI and more recently ^{19}F-labelling approaches (doi: 10.1259/bjr.20150375).

NP approaches can also pay a role in Nuclear Medicine, and several approaches are available for combining NPs and radioactive molecular imaging in translational research and clinical trials. The specific labelling of NPs with gamma-emitting radionuclides for single-photon emission CT (SPECT) imaging, positron-emitting radioisotopes for positron emission tomography (PET) and multimodal nuclear imaging approaches are all currently being tested (doi: 10.1259/bjr.20150185). Despite the great potential of NPs in diagnostic imaging currently only one agent, iron oxide NPs, is being utilized clinically. The enhanced permeability and retention effect is key to the delivery of diagnostic NP agents, and the tunability of these for use with MRI, CT, optical imaging, photoacoustic imaging, PET and SPECT needs to be optimized to deliver clinical potential for nanotheranostics and image-guided drug delivery (doi: 10.1259/bjr.20150207).

In the therapeutic space, only one metal-based NP is in a Phase 1 clinical trial at present (Pottier et al); however, many tumour types could potentially benefit from combinations of NPs with radiotherapy if the potential of an increased therapeutic window can be delivered. For example, in prostate cancer, several approaches are currently being evaluated in pre-clinical studies for combinations of NPs with not only external beam radiotherapy but also with brachytherapy (doi: 10.1259/bjr.20150256).

The future for the application of NPs holds significant potential, and we hope that this selection of articles will give *BJR* readers a taste of the challenges and opportunities for NPs to revolutionize diagnostic imaging and radiotherapy.

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